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RENEWABLE ENERGY

October 2017

Offshore Wind R&D Newsletter

Celebrating a Year of Progress for Offshore Wind

Letter from the Wind Energy Technologies Office's Deputy Director

As the wind industry gathers at the American Wind Energy Association (AWEA) Offshore WINDPOWER 2017 conference, we celebrate a year of progress and change for the U.S. offshore wind industry. At the end of 2016, the nation's first commercial offshore wind farm—Block Island Wind Farm—completed development off the coast of Rhode Island. Since then, more states have committed to expanding their offshore wind energy resources. And global market price declines promise to spur new development.

There have also been changes at the Energy Department's Wind Energy Technologies Office (WETO). After 6 years as the office's Director, José Zayas has taken a position in the private sector where he will continue to work in the renewable energy industry. Under Jose's tenure, wind energy became a mainstream, affordable, reliable, and domestic option that brings jobs and energy independence to the United States. Thank you to José for his outstanding vision, leadership, and enthusiasm. We wish him the best of success in his new venture.

WETO is delighted to introduce Dr. Valerie Reed as the new Acting Director. Valerie has been with the Energy Department for more than 20 years. Please visit the U.S. Department of Energy (DOE) booth in the Palm Room at 5:45 p.m. Tuesday to meet our team and the new acting director.

This fall 2017 edition of the Wind Research and Development (R&D) Newsletter features a variety of articles about Energy Department activities related to offshore wind energy. One exciting example is a new open-source technology developed by Pacific Northwest National Laboratory (PNNL) designed to detect birds and bats that may interfere with offshore turbines. Please keep reading for in-depth updates on research highlights—and go to our projects map for a comprehensive look at our full R&D portfolio: https://energy.gov/eere/wind/wind-energy-technologies-office-projects-map.

WETO also recently released the *2016 Offshore Wind Technologies Market Report,* which found decreasing global costs and stronger state policy commitments leading to increased confidence in the U.S. offshore wind market. The report also identified new technology trends, such as siting projects further from shore, and highlighted new policies that support the development of more than 4,000 megawatts (MW) of offshore wind. Currently, the U.S. offshore wind project development pipeline includes more than 20 projects totaling 24,135 MW of potential installed capacity.

On behalf of my colleagues and everyone at WETO, we are excited to play a key role in the continued expansion of offshore wind energy in the United States.

Sincerely,

Jim Ahlgrimm
Deputy Director,
Wind Energy Technologies Office

IN THIS ISSUE

Block Island Wind Farm off the coast of Rhode Island is the first commercial offshore wind farm in the country. The Northeast United States holds great economic promise for offshore wind development. *Photo courtesy of Gary Norton, NREL 41193*

New Offshore Wind Study Assesses Economic Potential Through 2030

A new study found considerable economic potential for offshore wind development in the United States. The study, titled "An Assessment of the Economic Potential of Offshore Wind in the United States from 2015 to 2030," provides insight into the variation of wind resources and economic potential for offshore wind in all of the U.S. coastal regions through 2030. Researchers evaluated the offshore wind economic potential of more than 7,000 U.S. coastal sites by utilizing descriptive statistics and high-resolution heat maps of levelized cost of energy (LCOE), levelized avoided cost of energy (LACE), and net value.

LCOE is a metric that captures the total cost of generating one unit of electricity and, in this study, is determined by examining cost factors such as average wind speed, distance from shore, soil depth, and availability of critical infrastructure.

Across all of the 7,000 coastal sites, researchers estimated LCOE to range between $130 per megawatt-hour (MWh) and $450 per MWh in 2015 and to decline to between $80 per MWh and $220 per MWh by 2027, without consideration for subsidies or renewable portfolio standards. The study found significant economic potential for offshore wind development in the Northeast United States and along the eastern shore of Virginia by 2027.

"We saw the greatest amount of economic potential identified in the New England area," said Philipp Beiter, who conducted the study with Walt Musial, Levi Kilcher, Michael Maness, and Aaron Smith of DOE's National Renewable Energy Laboratory (NREL). The best near-term potential is in New England, but there are also pockets of economic potential elsewhere, such as along the Gulf Coast or off the shores of California.

The economic potential shows the greatest initial promise in the New England area mainly because of the shallower water depths and the distance of potential offshore wind sites to the shore. The floor of the Atlantic seaboard offers a more gradual drop in elevation than that of the Pacific, which drops more dramatically close to shore. The proximity of wind resources to shore can affect operation and maintenance costs, while ocean depth can complicate the installation of wind turbines. Deeper waters would require floating turbines, a technology still in its infancy.

"Cost reduction has been the primary goal of the offshore wind program at NREL and DOE," said report co-author Musial. "We have found that there are numerous geographic variables that affect the bottom line, and they must be understood in the proper context. Our new cost model takes into account a wide range of spatial conditions for the waters off the coast of the United States that allow us to target global and regional cost reduction opportunities that were previously not possible."

Although LCOE is a good measure of how much electrical generation can cost, it does not capture how a generation source—such as offshore wind—adds value to the electric system. LACE considers factors, such as the cost of competing technologies, demand patterns, and transmission constraints, to approximate how much value a technology may add over its expected lifetime—and how much the market might be willing to pay for offshore wind. Taken together, the difference between LCOE and LACE indicates the net value of offshore wind.

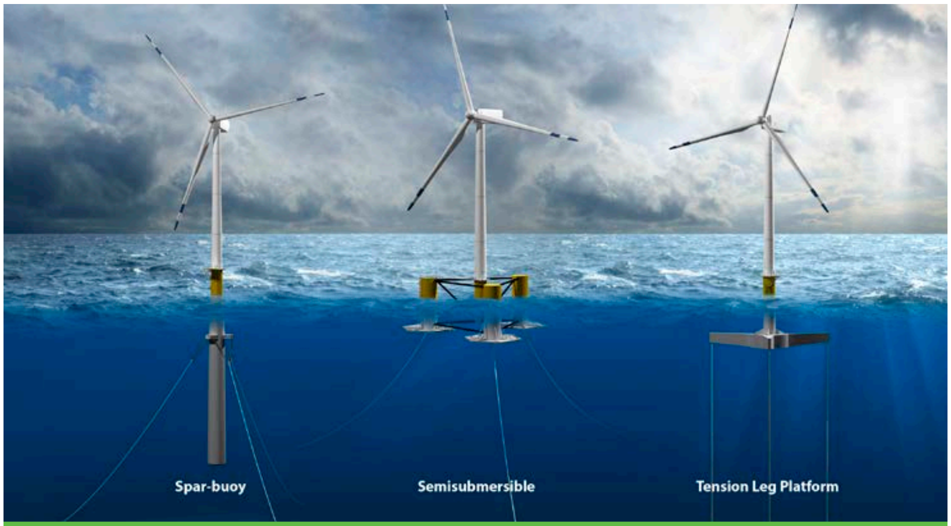
The results of this study will enable initial assessments of offshore wind as a part of energy development and portfolio planning in the United States. Even though detailed site-specific assessments remain essential for any offshore wind project, this study is the first to provide a comprehensive assessment of the economic potential for offshore wind across major U.S. coastal regions.

The study can be found at *https://www.nrel.gov/docs/fy17osti/67675.pdf.* ■

Offshore Floating Vertical-Axis Wind Turbine Project Identifies Promising Platform Design

A new floating, vertical-axis wind turbine (VAWT) platform design may enable offshore wind developers in the United States to access the country's vast deep-water offshore wind resource. DOE's *Wind Vision* Report and *National Offshore Wind Strategy* explore a scenario in which 86 gigawatts of offshore wind turbines will be installed by 2050. Reaching a competitive LCOE with existing energy sources is essential to achieving these goals and the industry's commercial success.

A recently completed study by Sandia National Laboratories (Sandia) and Stress Engineering Services identified a VAWT platform design that may help decrease the LCOE of offshore wind. The study compared floating offshore platform designs to identify a cost-optimal floating platform that meets the operational conditions, which includes variables like the operational wind speed range of the VAWT and the site's wave height distribution. Six designs were initially selected for analysis, chosen based on an initial survey and a first-principles analysis. The initial systems captured the various stability mechanisms available to floating systems: deep-draft ballasting, buoyancy, waterplane (the area of the platform that displaces the water), and tensioned mooring. Each of the six concepts utilizes one or more of these three stabilizing mechanisms in the design.



A new study from Sandia identified tension leg platforms as the most promising floating wind design for VAWTs. *Illustration by Josh Bauer.*

During this initial phase, a tension leg platform (TLP) with a hull made of multiple cylindrical columns was identified as the most promising selection from a cost perspective. Additionally, the TLP mooring scheme offered some performance benefits resulting from reduced platform motions and a smaller mooring anchor footprint.

Shorter mooring cables and lower installation costs reduce the TLP's cost. The system is designed to be towed offshore with the rotor installed, an advantage that makes installation cheaper. Stress Engineering Service's favorable platform cost estimate for the VAWT TLP challenges—and is challenged by—trends in commercial floating wind turbine platforms, which have favored semisubmersible or spar concepts.

"The TLP offers some interesting performance benefits resulting from the small roll and pitch motions, such as increased energy capture and reduced inertial loading on the tower and blades," said Brandon Ennis, Sandia's Wind Energy Technologies department offshore technical lead. "Combined with a favorable cost estimate, this suggests that these concepts may merit further investigation and consideration for offshore floating wind turbine platforms."

The platform and VAWT design and cost estimates were used in an LCOE analysis to estimate the total system cost for a floating VAWT offshore wind plant. A horizontal-axis wind turbine has a substantially higher center of gravity and distinct loading conditions, so Sandia's platform design and analysis would need to be extended to apply to both vertical and horizontal axes.

This analysis produced a range of estimates for VAWT turbines, with low-end values of 15–20 cents per kilowatt-hour for the LCOE, and identified the statistic's largest contributing sources. Details of the platform identification and selection and system LCOE analyses are documented in a technical report to be released this fall and housed on the Sandia offshore wind webpage located at *windpower.sandia.gov/offshore*. ■

A Renewable Future for the Oil and Gas Industry

After decreasing prices of crude oil have forced layoffs throughout the oil and gas industry, some of the players in the offshore oil and gas industry are looking toward a new future: offshore wind. Combining the nascent offshore wind industry with decades of offshore engineering, manufacturing, and installation know-how creates an opportunity for traditionally offshore oil and gas companies and rising-star renewables to thrive.

"As oil and gas companies look to 'unconventional' energy markets, right now is the perfect time for oil and gas companies to fully engage in the offshore wind industry," says Alana Duerr, DOE's offshore wind lead.

When Duerr attended the 2017 Offshore Wind Executive Summit: The Parallels of Wind, Oil and Gas, she was surprised to find that less than 15% of the attendees identified themselves as working in the wind industry, and that more than 50% of the event's attendees had not yet dipped their toes into the waters of offshore wind.

Alana Duerr, DOE's offshore wind lead.

"You're hitting a whole new group of people with deep knowledge of the challenges that come with working in the offshore environment and the energy market, but who don't yet have the experience in the offshore wind space," Duerr says.

The good news is that oil and gas companies may find the world of offshore wind familiar. Many technologies used in the offshore wind industry represent innovations that have stemmed from the offshore oil and gas industry. Foundations are fabricated in the same yards that build oil rigs, jacket substructures used for offshore drilling rigs are used in offshore wind, and all of the different floating foundations proposed for offshore wind have their roots in deep-water drilling.

But it is not just their experience with similar technologies that makes oil and gas companies valuable to the offshore wind industry. The marine environment presents its own unique challenges. For example, construction in the open ocean requires a highly skilled crew. When Deepwater Wind built the Block Island Wind Farm, they ultimately had to complete the foundation and turbine installation operations using vessels from the Gulf of Mexico that have been used in the oil and gas industry.

"There's significant engineering know-how, and construction and installation experience in the Gulf because that's where the oil and gas market has grown in the United States," Duerr says. "There's a role for these oil and gas service suppliers to play in this new U.S. industry, as they have significant experience in offshore construction that is not present on the Atlantic coast."

Bringing oil and gas service companies into a new industry is not always simple. Duerr would like to see more companies working in oil and gas explore the potential of working in the offshore wind industry. Success for the "first movers" has relied on finding champions: someone in the company who "has an idea, pursues it, and starts to make noise about it," Duerr says.

Currently, Europe is the global leader in the offshore wind manufacturing space, but transporting materials across the Atlantic comes at a premium. Much like the Block Island Wind Farm, it is expected that foundations for the initial offshore wind projects will be shipped from Gulf Coast facilities—but once the industry's construction pace intensifies, Duerr expects to see companies expanding to the East Coast. Construction for Block Island Wind Farm's six turbines did not require a purpose-built shipyard, but developing larger-scale offshore wind farms could require specialized manufacturing and assembly lines for offshore wind foundations to reduce the cost of foundations.

"Typical shipyards in the Gulf of Mexico are used for one-off type manufacturing; however, efficiently and effectively fulfilling an order of 50 offshore wind foundations at a competitive price may require some significant changes to existing manufacturing facilities or investment in new ones. New facilities will likely be located closer to the current offshore wind market demands on the East Coast," Duerr says.

There are challenges to face, but many of the solutions lie within U.S. domestic expertise. Luckily, oil and gas companies can bring their knowledge and experience in developing large-scale offshore infrastructure projects up the Atlantic seaboard to create a thriving stateside industry for offshore wind energy, thereby moving the dial toward a cleaner, more sustainable future. ■

ThermalTracker: The Secret Lives of Bats and Birds Revealed

American offshore wind turbines have the gross potential to produce over 2,000 gigawatts of power—more than double the amount of energy consumed by the United States each year. Offshore wind is consistent, abundant, and reliable, making it a promising source of energy near heavily populated coastal areas. When planning offshore wind projects, collecting data on the abundance of birds and bats informs project siting. Post-construction monitoring is also important to ensure project effects are sustainable and understood.

Exactly how different bat and bird taxonomic families behave in the presence of turbines and the potential effects of offshore wind farms on bat and bird flight and site use patterns has not been fully characterized. As a result, researchers at PNNL are working to ensure that offshore wind safely coexists with wildlife. By better understanding the different species affected—where they live and where and when they fly—developers can accelerate the environmentally responsible siting and permitting of offshore wind farms.

Continuously monitoring offshore locations provides a complete picture of the animals' behavior patterns at those sites. However, limited accessibility, harsh weather conditions, and nocturnal migrations of bats and birds make monitoring offshore locations difficult. Using thermal video, PNNL researcher

Shari Matzner uses a thermal video camera and ThermalTracker to identify wildlife in Sequim Bay, Washington.
Photo by Eric Francavilla, PNNL

Shari Matzner found a way around these limitations. Thermal video works both day and night and in low-visibility conditions. Even better, it is a mature, cost-effective technology.

Matzner recorded animals off the Washington coast with a thermal video camera and developed a software application called ThermalTracker. The open-source software quantifies the flight tracks of birds and bats by the time of day, direction of travel, relative size of the animal, and more. This information can be used to determine which taxonomic families of these animals live offshore. ThermalTracker characterizes and quantifies these data using a standard desktop computer. ThermalTracker's postprocessing output can be readily analyzed using common statistical software like Microsoft Excel.

After developing ThermalTracker, Matzner tested it for accuracy—and found the software detected 81% of all the birds and bats. The missed detections occurred when animals were too far from the camera or the weather conditions were too cloudy. ThermalTracker's data processing can be performed in roughly the same amount of time as the video duration, implying real-time processing is possible. When human experts reviewed the same footage, it took, on average, five times longer to generate the same data as ThermalTracker.

> Developing technology to detect bird and bat activity will promote a better understanding of the nature of wildlife risks.

Two ThermalTracker models were developed for species identification. The first combines flight track data with the time of day, allowing researchers to classify observed animal species such as gull, tern, swallow, or bat. The second ThermalTracker model identifies different North American sea bird and bat taxonomic families based on wing-beat frequencies. The two models work together to accurately identify animals.

The next stage of ThermalTracker's development will incorporate stereo vision to estimate the location of an animal and its approximate size to improve identification. An updated algorithm detects animals as video is being recorded and only saves video when a bird or bat is detected. With less data to store, the system can be used for long-term observation and provide more complete information.

Biologists at the nonprofit Biodiversity Research Institute (BRI) are currently testing the system off the coast of Maine.

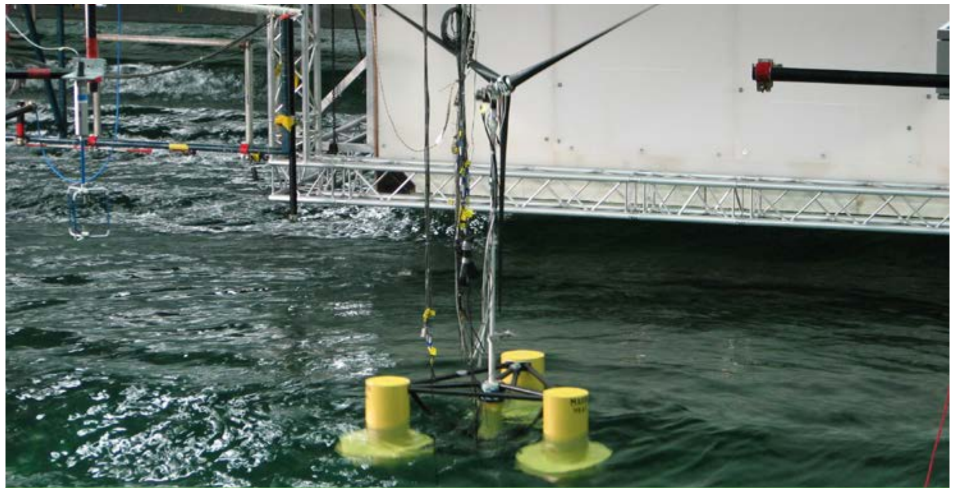
"Developing technology to detect bird and bat activity at terrestrial and offshore wind farms will promote a better understanding of the nature of wildlife risks—or lack thereof—at any type of wind farm and reduce uncertainty about the potential for unintended impacts during operation," said BRI Deputy Director Wing Goodale. "These cameras could provide a reliable method of detecting bird and bat response to offshore wind projects, where it is not possible to conduct wildlife monitoring by traditional means."

Matzner and her colleagues will use the BRI field biologists' notes to refine ThermalTracker algorithms later this year. ■

NREL Paves the Way for Floating Offshore Wind Semisubmersible Model Validation

NREL researchers have been leading an international effort to validate offshore wind models by comparing physical test data from offshore wind energy systems against the simulated data produced by modeling tools. Analyzing offshore wind system modeling tools enables the development of more innovative and cost-effective designs. This project, called the Offshore Code Comparison Collaboration, Continued, with Correlation (OC5), ran under the International Energy Agency Wind Research Task 30 and involved more than 30 countries and research institutions.

To test numerical models of the OC5-DeepCwind system, researchers used measurement data from a $1/50^{th}$-scale test campaign performed at the Marine Research Institute Netherlands offshore wave basin. Model validation assessments compared the ultimate and fatigue loads that were predicted by the modeling tools against the measured data for eight different wave-only and combined wind-and-wave test cases. The measured data included aerodynamics and hydrodynamics loading for fixed-bottom systems and mooring loads for floating systems at both model-scale tank testing and full-scale open-ocean testing.



Models of the OC5-DeepCwind system were validated by comparing simulated data with physical test data from semisubmersible offshore wind turbines. *Photo courtesy of Deepwater Floating Offshore Wind, NREL 19576*

The project involved participants from across the offshore wind industry field, including offshore wind designers, consultants, certifiers, developers, and research institutions. Results indicated that industry design tools adequately estimate the tower and mooring loads in the structure, but with a consistent underestimation for this system, which will require further investigation.

"Validated modeling tools can be used to develop optimized designs to reduce costs," said NREL project lead Amy Robertson. "With the involvement of so many industry partners, we are able to directly affect the knowledge and capabilities used throughout the industry."

Validation campaigns help to assess the accuracy of the offshore wind system modeling tools, provide a better understanding of the uncertainties in those tools, and identify areas for improvement—and are essential for reaching commercial maturity for offshore wind technologies. Validated modeling tools can then be used to develop optimized designs to meet DOE's goal of reducing the cost of offshore wind. ■

Wind Energy Continues Rapid Growth

America's wind industry added more than 8,200 MW of capacity and supported more than 101,000 jobs in 2016, according to three wind market reports released by WETO. These reports cover the offshore, land-based utility-scale, and distributed wind market sectors.

Improvements in the cost and performance of wind power technologies have driven wind additions and yielded low power sale prices for utility, corporate, and other purchasers. In 2016, wind supplied about 6 percent of U.S. electricity, and 14 states now get more than 10 percent of their electricity from wind.

According to the *2016 Offshore Wind Technologies Market Report*, the U.S. offshore wind project development pipeline includes more than 20 projects totaling 24,135 MW of potential installed capacity. Most of the near-term activity is concentrated off the Northeast coast, but projects are proposed in the Southeast Atlantic, the Pacific, the Gulf of Mexico, and the Great Lakes. Proposed floating offshore wind projects total 1,993 MW of announced capacity.

The report also found that news of declining European offshore wind project costs spurred confidence in the domestic U.S. offshore wind market. Several states—including Massachusetts, New York, and Maryland—have enacted new policy or bolstered existing policies.

The *2016 Wind Technologies Market Report* found utility-scale wind installations stand at more than 82 gigawatts, with Texas leading the nation with 20 GW of wind capacity. Iowa and South Dakota produced more than 30% of their electricity through wind, and 12 other states exceeded 10%.

U.S.-based small wind turbine manufacturers accounted for more than $240 million in small wind turbine export sales, according to the *2016 Distributed Wind Market Report*. The report also indicates that roughly 77,000 turbines are installed across all 50 states, the District of Columbia, Guam, Puerto Rico, and the U.S. Virgin Islands.

Read the full reports at *energy.gov/eere/wind/2016-wind-market-reports*. ■

DOE Wind Energy Technologies Office and Awardee Presentations at AWEA Offshore WINDPOWER 2017

TUESDAY, OCTOBER 24

Welcome and Opening Session

9:15–10:45 a.m.
Keynote Speaker: Timothy Unruh, Deputy Assistant Secretary for Renewable Power, DOE

Assessing Initial U.S. Offshore Wind Project Costs, Philipp Beiter, Energy Markets and Policy Analyst, NREL

National Agenda and Rationale for Offshore Wind Standards

4:15 p.m.–5:30 p.m.
Walt Musial, Manager, Offshore Wind, NREL

Poster Presentations

11:45 a.m.–1:45 p.m.

- *Development and Verification of the Soil-Pile Interaction Extension for SubDyn*, Rick Damiani, Senior Engineer, NREL
- *Comparison of Ultimate Loads from Fully- and Sequentially-Coupled Dynamic Analysis Approach*, Fabian Wendt, Research Engineer, NREL
- *Advanced Wind Turbine Development for Floating Support Structures*, John Arimond, Business Development Manager, University of Maine
- *Floating Offshore Wind in Maine: New England Aqua Ventus I – Project Updates*, Habib Joseph Dagher, Executive Director, University of Maine
- *Estimating the Value of Offshore Wind on the United States' Eastern Coast*, Ryan Wiser, Senior Scientist, Lawrence Berkeley National Laboratory

Wind Events

AWEA Wind Energy Fall Symposium 2017
Albuquerque, New Mexico
November 7–9, 2017
www.awea.org/events/event.aspx?eventid=50113

Dynamic Line Rating Workshop
Idaho Falls, Idaho
November 7–9, 2017
https://www.uvig.org/event/2017-dynamic-line-rating-workshop/

Southeastern Wind Coalition's Southeast Wind Energy Conference
Atlanta, Georgia
January 25, 2018
www.sewind.org/industry-events/details/sewc-southeast-wind-energy-conference

AWEA Wind Project Operations and Maintenance Safety Conference 2018
San Diego, California
February 27–28, 2018
www.awea.org/events/event.aspx?eventid=56459&navItemNumber=656

Distributed Wind 2018
Washington, D.C.
February 28–March 1, 2018
distributedwind.org/event/distributed-wind-2018/2018-02-28/

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